US009051793B2

(12) United States Patent
Makkar et al.

(10) Patent No.: US 9,051,793 B2
(45) Date of Patent: Jun. 9, 2015

(54) APPARATUSES AND METHODS FOR STABILIZING DOWNHOLE TOOLS

(75) Inventors: **Navish Makkar**, Houston, TX (US); **Brian Cruickshank**, Montgomery, TX (US); **Charles Dewey**, Houston, TX (US); **Michael G. Azar**, The Woodlands, TX (US)

(73) Assignee: **Smith International, Inc.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 748 days.

(21) Appl. No.: **13/324,265**

(22) Filed: **Dec. 13, 2011**

(65) **Prior Publication Data**

US 2013/0146361 A1 Jun. 13, 2013

(51) **Int. Cl.**
E21B 10/32 (2006.01)
E21B 17/10 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 10/322*** (2013.01); ***E21B 10/32*** (2013.01); ***E21B 17/1078*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 10/32
USPC 175/263, 265, 267
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,823,901	A *	2/1958	Kammerer	166/55.8
3,224,507	A	12/1965	Cordary et al.	
3,331,439	A *	7/1967	Sanford	166/55.8
3,425,500	A	2/1969	Fuchs	
4,055,226	A	10/1977	Weber	
4,938,291	A *	7/1990	Lynde et al.	166/55.8
7,314,099	B2	1/2008	Dewey et al.	
7,770,664	B2	8/2010	Laird et al.	
7,900,717	B2	3/2011	Radford et al.	
7,954,564	B2	6/2011	Makkar et al.	
2010/0018779	A1 *	1/2010	Makkar et al.	175/382
2010/0276201	A1 *	11/2010	Makkar et al.	175/57
2013/0168076	A1 *	7/2013	Davis	166/55.8

FOREIGN PATENT DOCUMENTS

WO 2010126938 11/2010

OTHER PUBLICATIONS

International Search Report and Written Opinion of PCT/US2012/069356 dated Mar. 28, 2013: pp. 1-12.

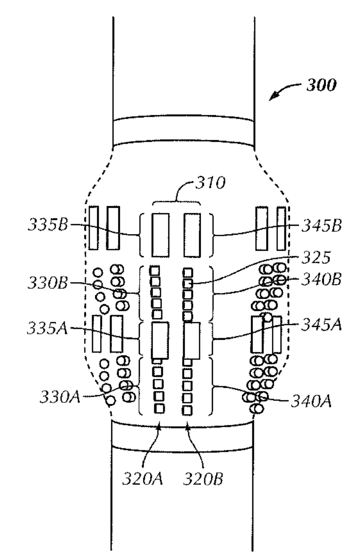
* cited by examiner

Primary Examiner — Giovanna C Wright
(74) *Attorney, Agent, or Firm* — Osha Liang LLP

(57) **ABSTRACT**

A secondary cutting structure for use in a drilling assembly includes a tubular body, and a block, extendable from the tubular body, the block including a first arrangement of cutting elements disposed on a first blade, a first stabilization section disposed proximate the first arrangement of cutting elements, a second arrangement of cutting elements disposed on the first blade, and a second stabilization section disposed proximate the second arrangement of cutting elements. A method of drilling includes disposing a drilling assembly in a wellbore, the drilling assembly including a secondary cutting structure having a tubular body and a block, extendable from the body, the block including at least three blades, actuating the secondary cutting structure, wherein the actuating includes extending the block from the tubular body, and drilling formation with the extended block.

15 Claims, 11 Drawing Sheets



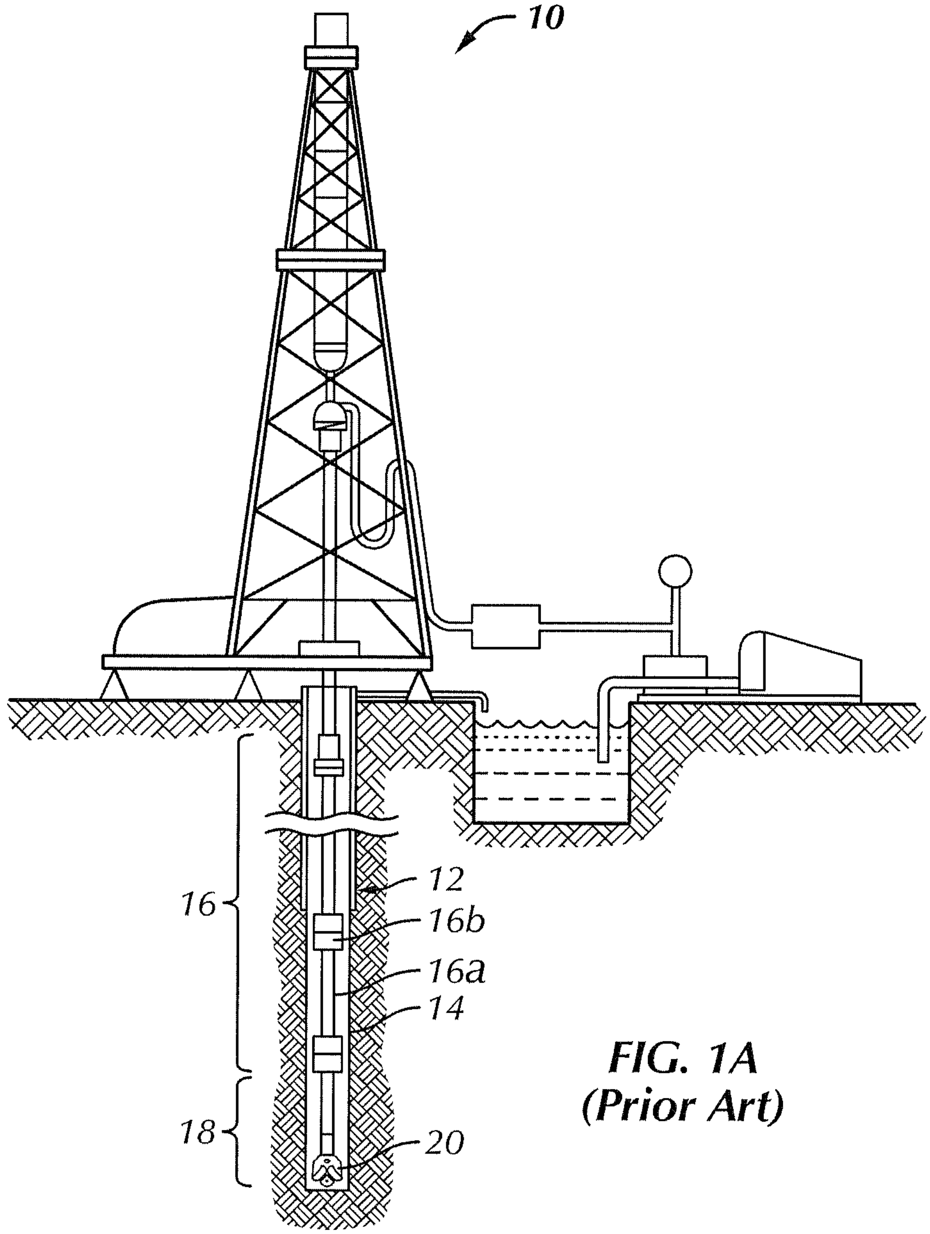


FIG. 1A
(Prior Art)

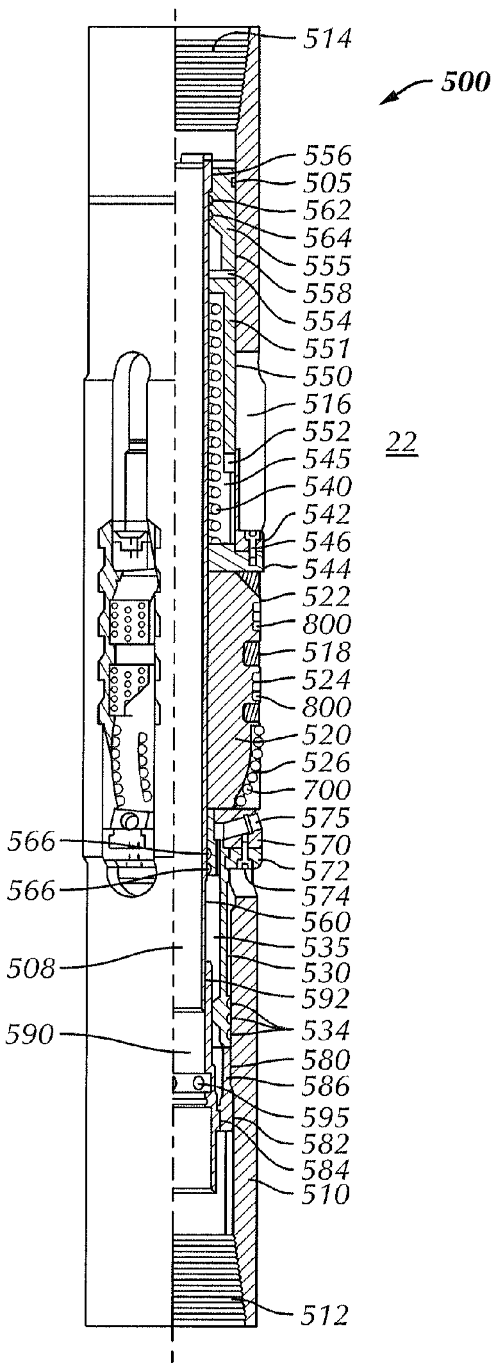

514
500
556
505
562
564
555
558
554
551
550
516
552
545
540
542
546
544
522
800
518
524
800
520
526
700
575
570
572
574
560
535
530
592
534
580
586
595
582
584
510
512
566
566
508
590
22

FIG. 1B

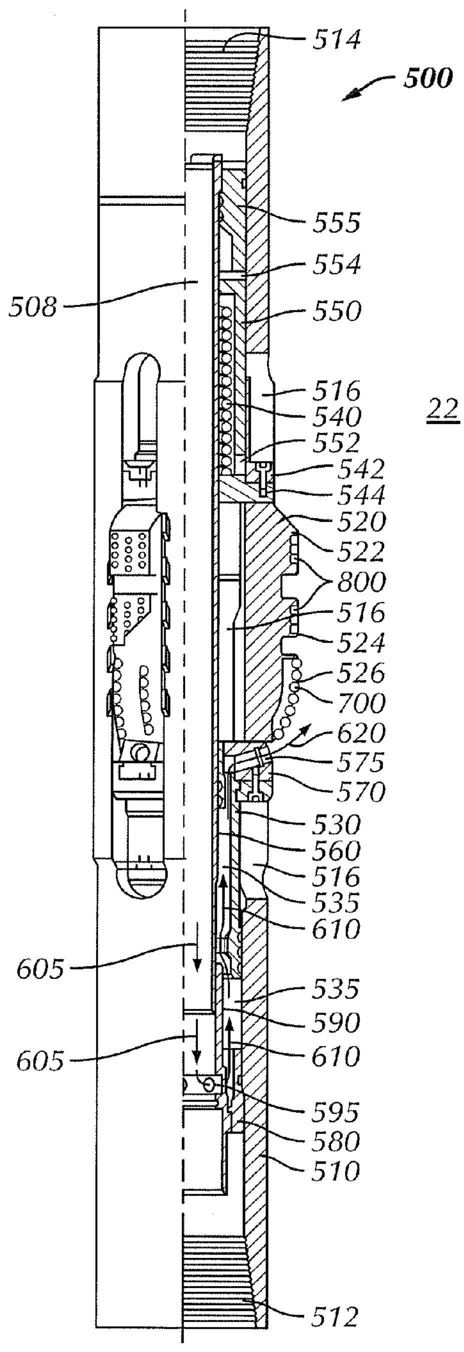

514
500
555
554
508
550
516
540
552
542
544
520
522
800
516
524
526
700
620
575
570
530
560
516
535
610
605
535
590
605
610
595
580
510
512
22

FIG. 1C

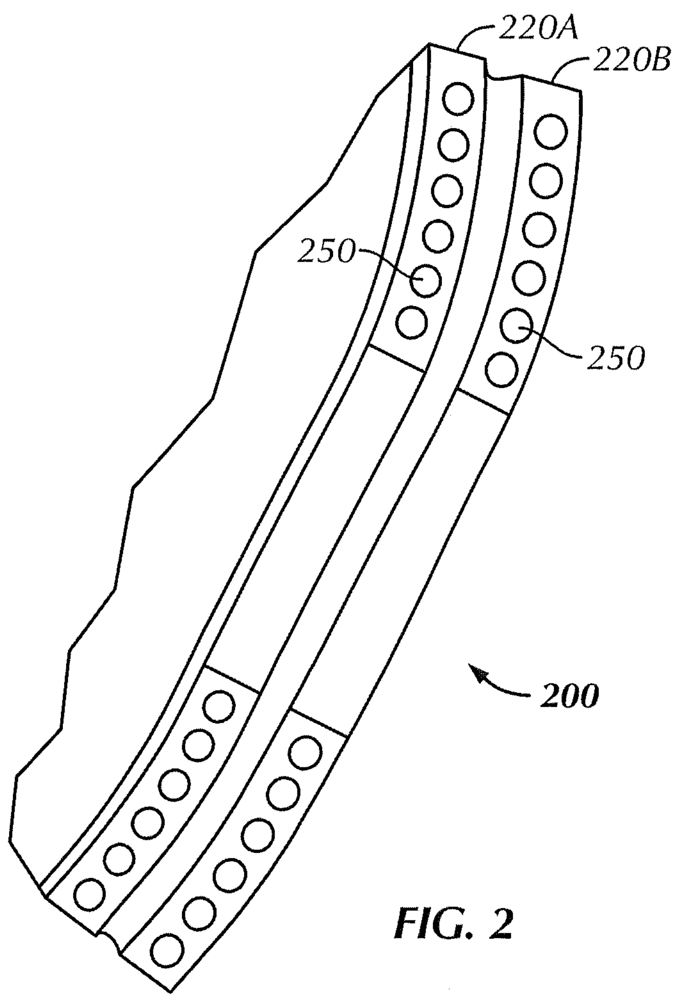


FIG. 2

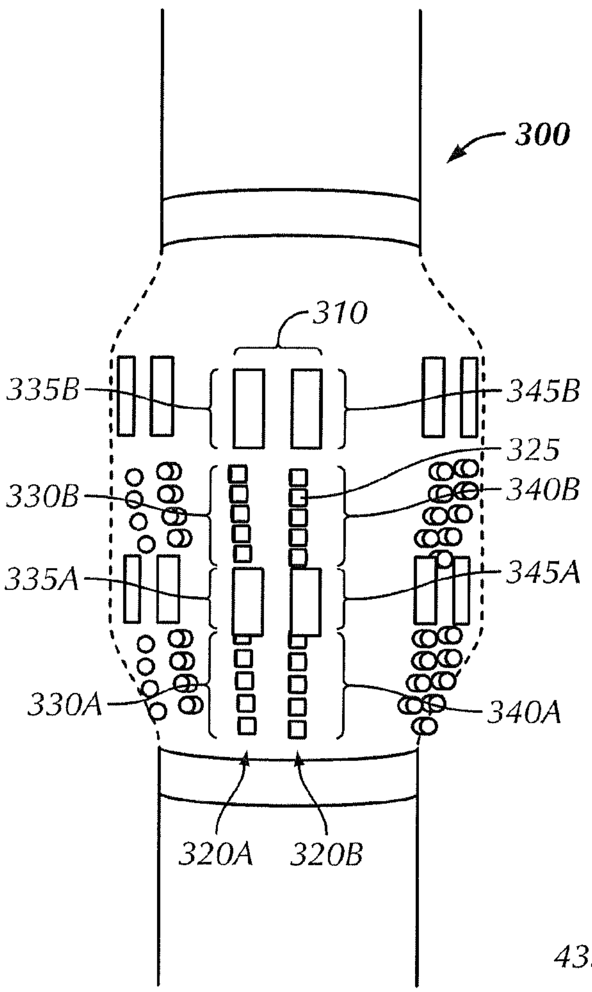

300
310
335B
345B
325
330B
340B
335A
345A
330A
340A
320A
320B

FIG. 3

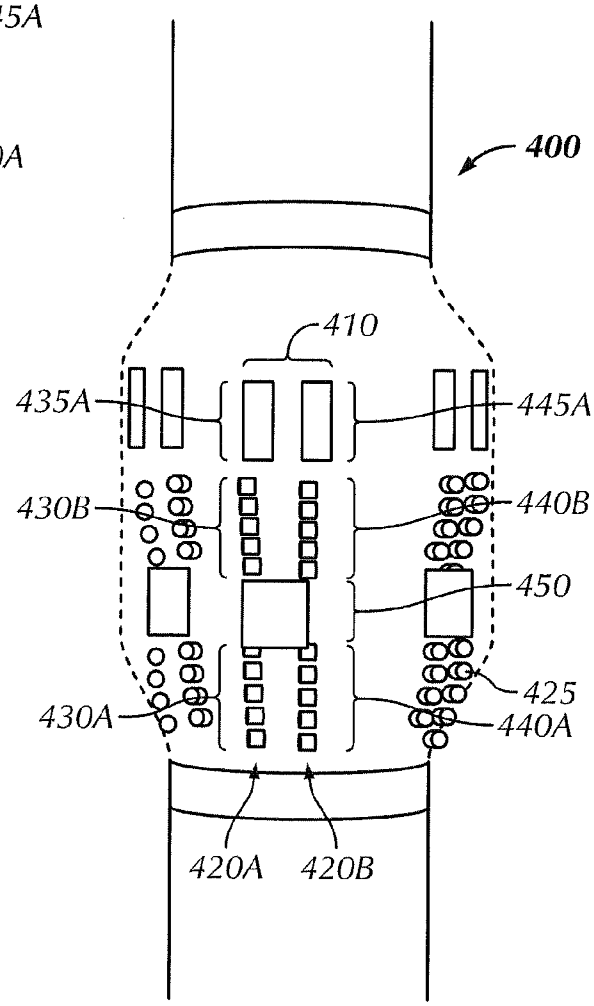

400
410
435A
445A
430B
440B
450
425
430A
440A
420A
420B

FIG. 4

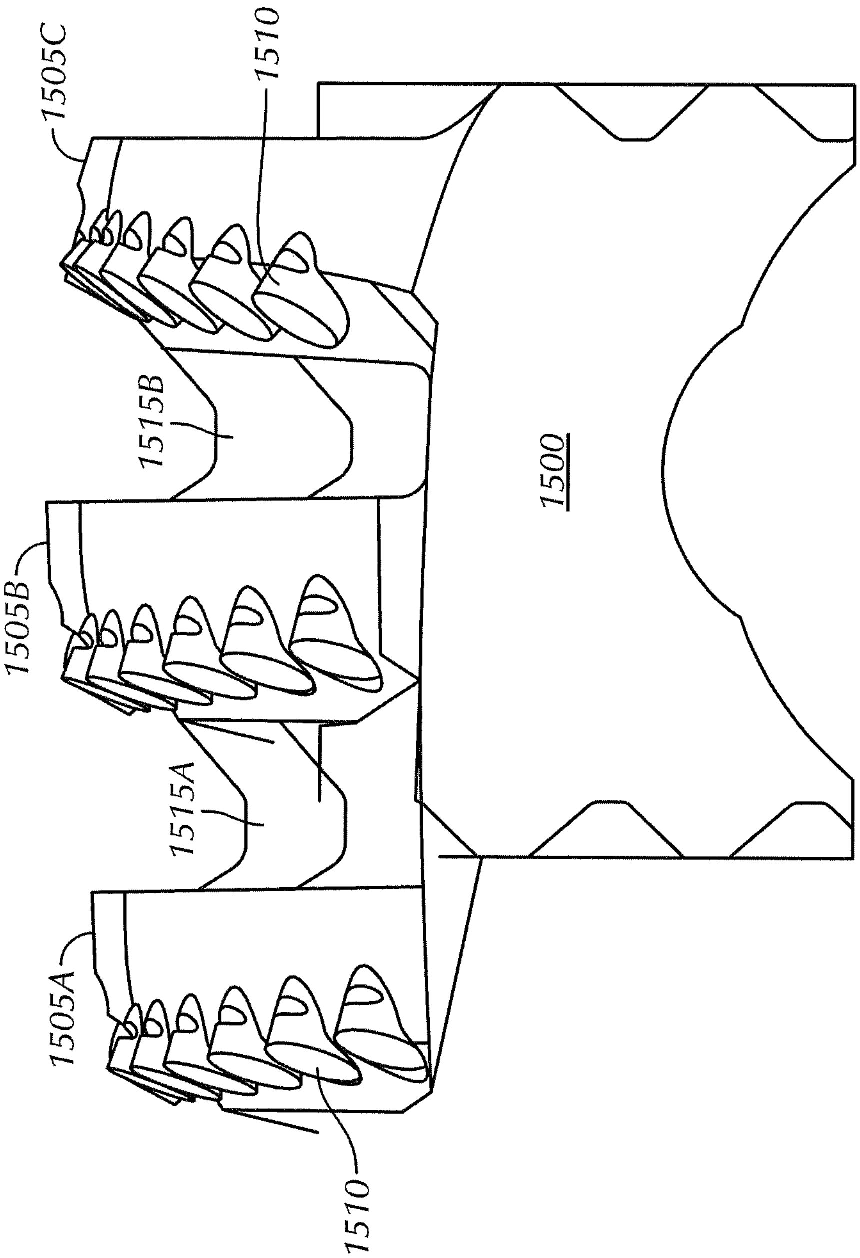


FIG. 5

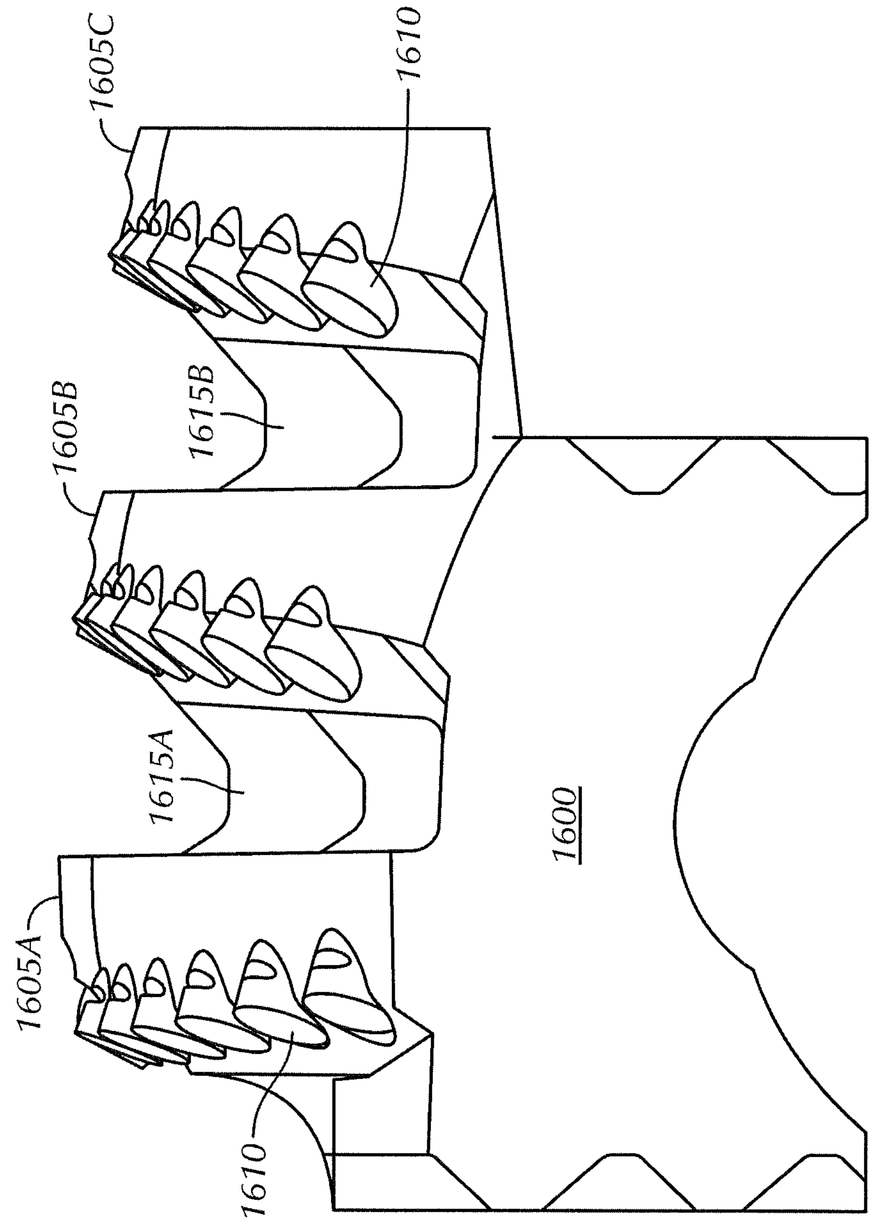


FIG. 6

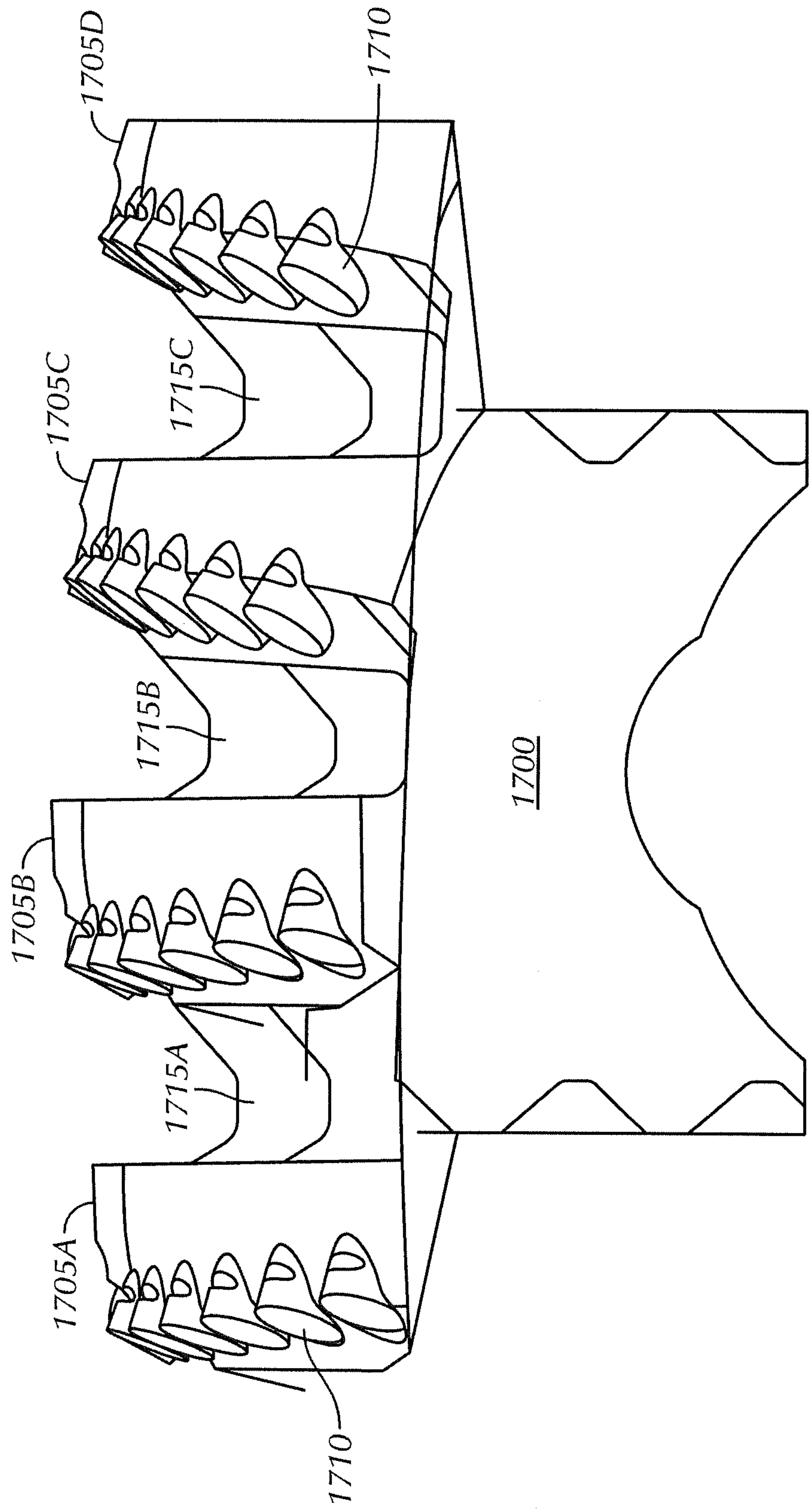


FIG. 7

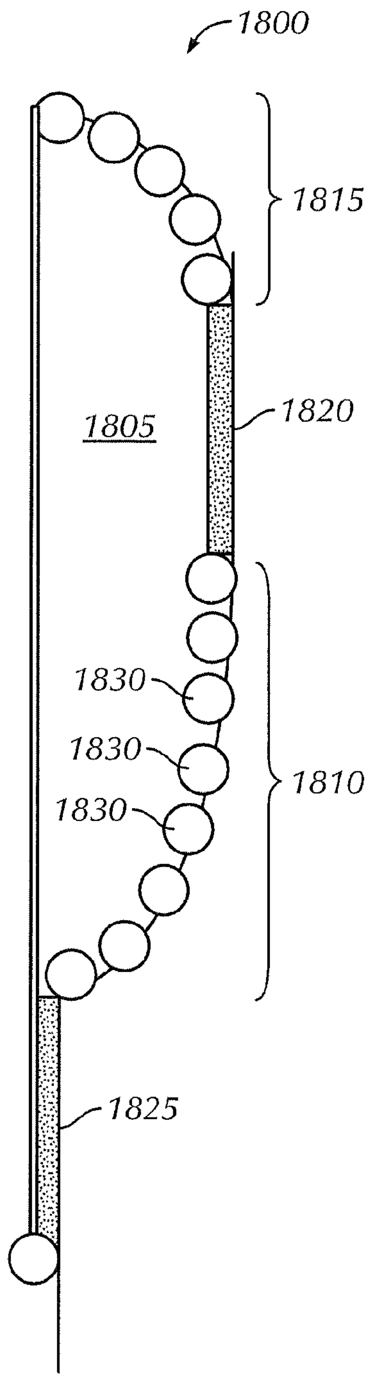

1800
1815
1805
1820
1830
1830
1830
1810
1825

FIG. 8

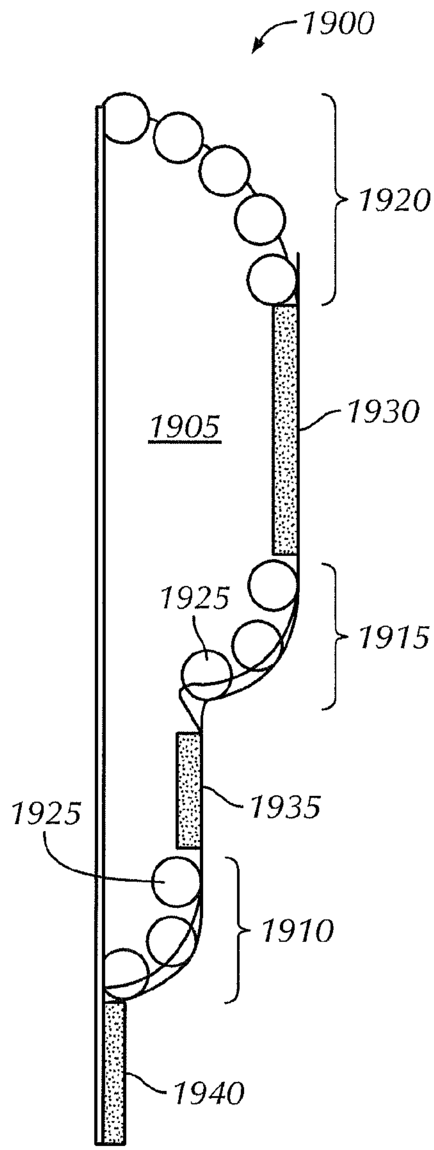

1900
1920
1905
1930
1925
1915
1935
1925
1910
1940

FIG. 9

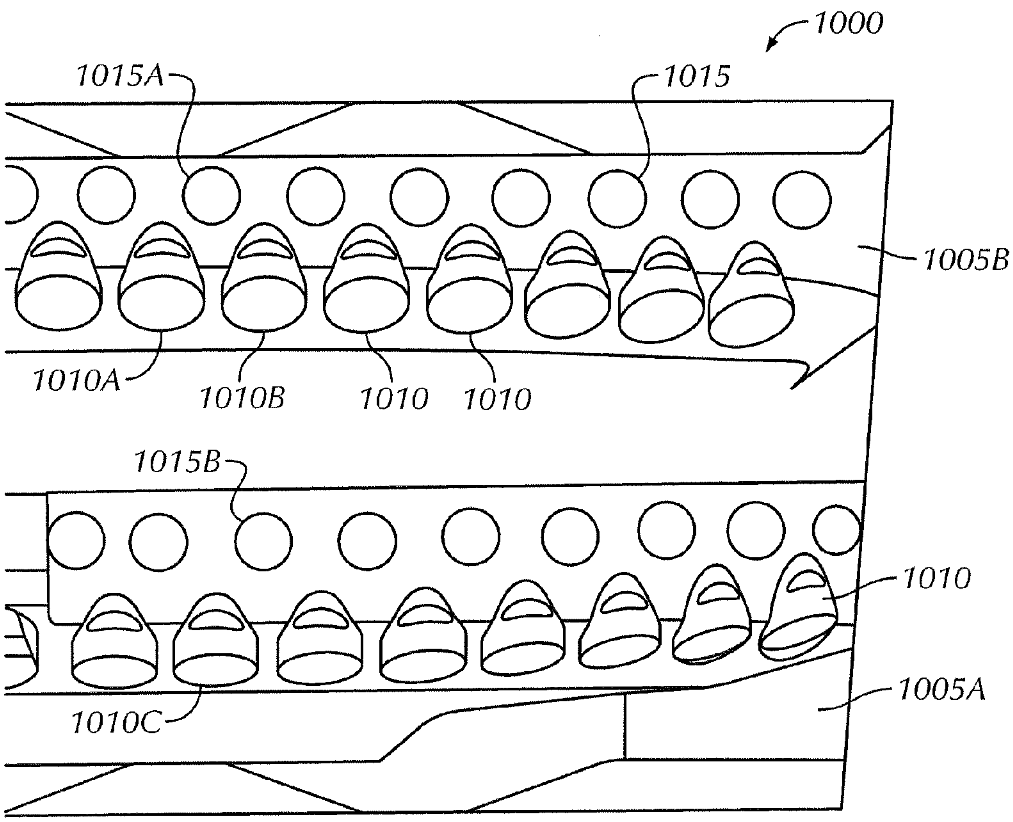

1000
1015A
1015
1005B
1010A
1010B
1010
1010
1015B
1010
1005A
1010C

FIG. 10A

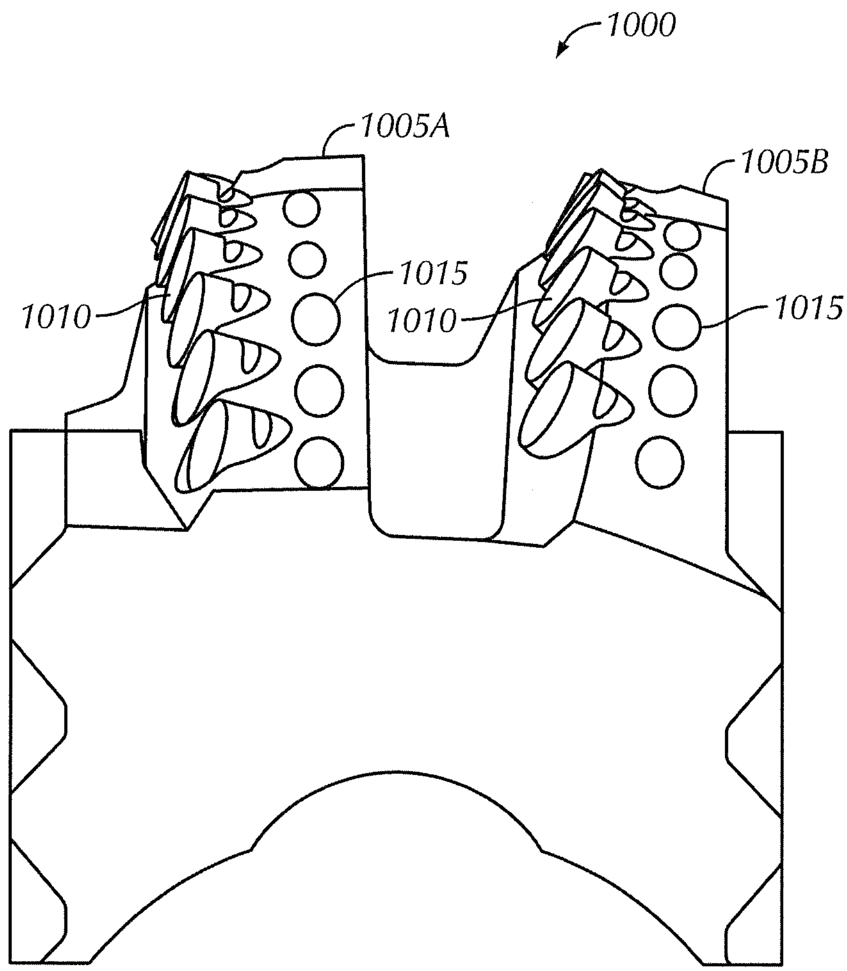


FIG. 10B

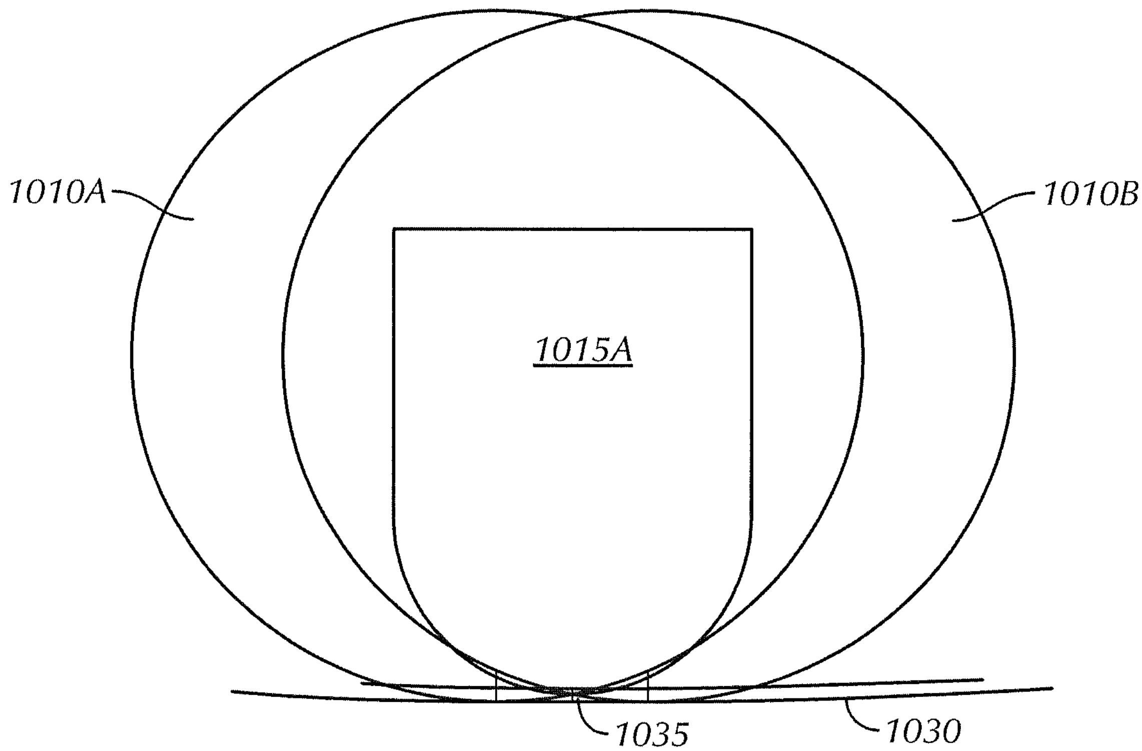


FIG. 10C

APPARATUSES AND METHODS FOR STABILIZING DOWNHOLE TOOLS

BACKGROUND

1. Field of the Invention

Embodiments disclosed herein relate to apparatuses and methods for drilling formation. More specifically, embodiments disclosed herein relate to apparatuses and methods for drilling formation with drilling tool assemblies having enhanced stabilizing features. More specifically still, embodiments disclosed herein relate to apparatuses and methods for drilling formation with expandable secondary cutting structure having enhanced stabilizing features.

2. Background Art

FIG. **1**A shows one example of a conventional drilling system for drilling an earth formation. The drilling system includes a drilling rig **10** used to turn a drilling tool assembly **12** that extends downward into a well bore **14**. The drilling tool assembly **12** includes a drilling string **16**, and a bottom-hole assembly (BHA) **18**, which is attached to the distal end of the drill string **16**. The "distal end" of the drill string is the end furthest from the drilling rig.

The drill string **16** includes several joints of drill pipe **16***a* connected end to end through tool joints **16***b*. The drill string **16** is used to transmit drilling fluid (through its hollow core) and to transmit rotational power from the drill rig **10** to the BHA **18**. In some cases the drill string **16** further includes additional components such as subs, pup joints, etc.

The BHA **18** includes at least a drill bit **20**. Typical BHA's may also include additional components attached between the drill string **16** and the drill bit **20**. Examples of additional BHA components include drill collars, stabilizers, measurement-while-drilling (MWD) tools, logging-while-drilling (LWD) tools, subs, hole enlargement devices (e.g., hole openers and reamers), jars, accelerators, thrusters, downhole motors, and rotary steerable systems. In certain BHA designs, the BHA may include a drill bit **20** or at least one secondary cutting structure or both.

In general, drilling tool assemblies **12** may include other drilling components and accessories, such as special valves, kelly cocks, blowout preventers, and safety valves. Additional components included in a drilling tool assembly **12** may be considered a part of the drill string **16** or a part of the BHA **18** depending on their locations in the drilling tool assembly **12**.

The drill bit **20** in the BHA **18** may be any type of drill bit suitable for drilling earth formation. Two common types of drill bits used for drilling earth formations are fixed-cutter (or fixed-head) bits and roller cone bits.

In the drilling of oil and gas wells, concentric casing strings are installed and cemented in the borehole as drilling progresses to increasing depths. Each new casing string is supported within the previously installed casing string, thereby limiting the annular area available for the cementing operation. Further, as successively smaller diameter casing strings are suspended, the flow area for the production of oil and gas is reduced. Therefore, to increase the annular space for the cementing operation, and to increase the production flow area, it is often desirable to enlarge the borehole below the terminal end of the previously cased borehole. By enlarging the borehole, a larger annular area is provided for subsequently installing and cementing a larger casing string than would have been possible otherwise. Accordingly, by enlarging the borehole below the previously cased borehole, the bottom of the formation can be reached with comparatively larger diameter casing, thereby providing more flow area for the production of oil and gas.

Various methods have been devised for passing a drilling assembly through an existing cased borehole and enlarging the borehole below the casing. One such method is the use of an underreamer, which has basically two operative states—a closed or collapsed state, where the diameter of the tool is sufficiently small to allow the tool to pass through the existing cased borehole, and an open or partly expanded state, where one or more arms with cutters on the ends thereof extend from the body of the tool. In this latter position, the underreamer enlarges the borehole diameter as the tool is rotated and lowered in the borehole.

A "drilling type" underreamer is typically used in conjunction with a conventional pilot drill bit positioned below or downstream of the underreamer. The pilot bit can drill the borehole at the same time as the underreamer enlarges the borehole formed by the bit. Underreamers of this type usually have hinged arms with roller cone cutters attached thereto. Most of the prior art underreamers utilize swing out cutter arms that are pivoted at an end opposite the cutting end of the cutting arms, and the cutter arms are actuated by mechanical or hydraulic forces acting on the arms to extend or retract them. Typical examples of these types of underreamers are found in U.S. Pat. Nos. 3,224,507; 3,425,500 and 4,055,226. In some designs, these pivoted arms tend to break during the drilling operation and must be removed or "fished" out of the borehole before the drilling operation can continue. The traditional underreamer tool typically has rotary cutter pocket recesses formed in the body for storing the retracted arms and roller cone cutters when the tool is in a closed state. The pocket recesses form large cavities in the underreamer body, which requires the removal of the structural metal forming the body, thereby compromising the strength and the hydraulic capacity of the underreamer. Accordingly, these prior art underreamers may not be capable of underreaming harder rock formations, or may have unacceptably slow rates of penetration, and they are not optimized for the high fluid flow rates required. The pocket recesses also tend to fill with debris from the drilling operation, which hinders collapsing of the arms. If the arms do not fully collapse, the drill string may easily hang up in the borehole when an attempt is made to remove the string from the borehole.

Recently, expandable underreamers having arms with blades that carry cutting elements have found increased use. Expandable underreamers allow a drilling operator to run the underreamer to a desired depth within a borehole, actuate the underreamer from a collapsed position to an expanded position, and enlarge a borehole to a desired diameter. Cutting elements of expandable underreamers may allow for underreaming, stabilizing, or backreaming, depending on the position and orientation of the cutting elements on the blades. Such underreaming may thereby enlarge a borehold by 15-40%, or greater, depending on the application and the specific underreamer design.

Typically, expandable underreamer design includes placing two blades in groups, referred to as blocks, around a tubular body of the tool. A first blade, referred to as a leading blade absorbs a majority of the load, the leading load, as the tool contacts formation. A second blade, referred to as a trailing blade, and positioned rotationally behind the leading blade on the tubular body then absorbs a trailing load, which is less than the leading load. Thus, the cutting elements of the leading blade traditionally bear a majority of the load, while cutting elements of the trailing blade only absorb a majority of the load after failure of the cutting elements of the leading blade. Such design principles, resulting in unbalanced load conditions on adjacent blades, often result in premature failure of cutting elements, blades, and subsequently, the underreamer.

Accordingly, there exists a need for apparatuses and methods of drilling formation having enhanced vibration control.

SUMMARY OF THE DISCLOSURE

In one aspect, embodiments disclosed herein relate to a secondary cutting structure for use in a drilling assembly, the secondary cutting structure including a tubular body, and a block, extendable from the tubular body, the block including a first arrangement of cutting elements disposed on a first blade, a first stabilization section disposed proximate the first arrangement of cutting elements, a second arrangement of cutting elements disposed on the first blade, and a second stabilization section disposed proximate the second arrangement of cutting elements.

In another aspect, embodiments disclosed herein relate to a secondary cutting structure for use in a drilling assembly, the secondary cutting structure including a tubular body, and a block, extendable from the tubular body, the block including a plurality of cutting elements disposed on a first blade, and at least one depth of cut limiter disposed intermediate the apex of at least two adjacent cuttings element.

In another aspect, embodiments disclosed herein relate to a secondary cutting structure for use in a drilling assembly, the secondary cutting structure including a tubular body, and a block, extendable from the tubular body, the block including at least three blades.

In yet another aspect, embodiments disclosed herein relate to a method of drilling, the method including disposing a drilling assembly in a wellbore, the drilling assembly including a secondary cutting structure having a tubular body and a block, extendable from the body, the block including at least three blades, actuating the secondary cutting structure, wherein the actuating includes extending the block from the tubular body, and drilling formation with the extended block.

Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1**A is a schematic representation of a drilling operation.

FIGS. **1**B and **1**C are partial cut away views of an expandable secondary cutting structure.

FIG. **2** is a side perspective view of a block of a reamer.

FIG. **3** is a side view of a reamer according to embodiments of the present disclosure.

FIG. **4** is a side view of a reamer according to embodiments of the present disclosure.

FIG. **5** is an end view of a block of a reamer according to embodiments of the present disclosure.

FIG. **6** is an end view of a block of a reamer according to embodiments of the present disclosure.

FIG. **7** is an end view of a block of a reamer according to embodiments of the present disclosure.

FIG. **8** is a side view of a reamer according to embodiments of the present disclosure.

FIG. **9** is a side view of a reamer according to embodiments of the present disclosure.

FIG. **10**A is a top view of a reamer block according to embodiments of the present disclosure.

FIG. **10**B is an end view of a reamer block according to embodiments of the present disclosure.

FIG. **10**C is a close-perspective representation of the reamer of FIGS. **10**A and **10**B according to embodiments of the present disclosure.

DETAILED DESCRIPTION

In one aspect, embodiments disclosed herein relate generally to apparatuses and methods for drilling formation. In another aspect, embodiments disclosed herein relate to apparatuses and methods for drilling formation with drilling tool assemblies having enhanced stabilizing features. In yet another aspect, embodiments disclosed herein relate to apparatuses and methods for drilling formation with expandable secondary cutting structure having enhanced stabilizing features.

Secondary cutting structures, according to embodiments disclosed herein, may include reaming devices of a drilling tool assembly capable of drilling an earth formation. Such secondary cutting structures may be disposed on a drill string downhole tool and actuated to underream or backream a wellbore. Examples of secondary cutting structures include expandable reaming tools that are disposed in the wellbore in a collapsed position and then expanded upon actuation.

Referring now to FIGS. **1**B and **1**C, an expandable tool, which may be used in embodiments of the present disclosure, generally designated as **500**, is shown in a collapsed position in FIG. **1**B and in an expanded position in FIG. **1**C. The expandable tool **500** comprises a generally cylindrical tubular tool body **510** with a flowbore **508** extending therethrough. The tool body **510** includes upper **514** and lower **512** connection portions for connecting the tool **500** into a drilling assembly. In approximately the axial center of the tool body **510**, one or more pocket recesses **516** are formed in the body **510** and spaced apart azimuthally around the circumference of the body **510**. The one or more recesses **516** accommodate the axial movement of several components of the tool **500** that move up or down within the pocket recesses **516**, including one or more moveable, non-pivotable tool arms **520**. Each recess **516** stores one moveable arm **520** in the collapsed position.

FIG. **1**C depicts the tool **500** with the moveable arms **520** in the maximum expanded position, extending radially outwardly from the body **510**. Once the tool **500** is in the borehole, it is only expandable to one position. Therefore, the tool **500** has two operational positions—namely a collapsed position as shown in FIG. **1**B and an expanded position as shown in FIG. **1**C. However, the spring retainer **550**, which is a threaded sleeve, may be adjusted at the surface to limit the full diameter expansion of arms **520**. Spring retainer **550** compresses the biasing spring **540** when the tool **500** is collapsed, and the position of the spring retainer **550** determines the amount of expansion of the arms **520**. Spring retainer **550** is adjusted by a wrench in the wrench slot **554** that rotates the spring retainer **550** axially downwardly or upwardly with respect to the body **510** at threads **551**.

In the expanded position shown in FIG. **1**C, the arms **520** will either underream the borehole or stabilize the drilling assembly, depending on the configuration of pads **522**, **524** and **526**. In FIG. **1**C, cutting structures **700** on pads **526** are configured to underream the borehole. Depth of cut limiters (i.e., depth control elements) **800** on pads **522** and **524** would provide gauge protection as the underreaming progresses. Hydraulic force causes the arms **520** to expand outwardly to the position shown in FIG. **1**C due to the differential pressure of the drilling fluid between the flowbore **508** and the annulus **22**.

The drilling fluid flows along path **605**, through ports **595** in the lower retainer **590**, along path **610** into the piston chamber **535**. The differential pressure between the fluid in the flowbore **508** and the fluid in the borehole annulus **22** surrounding tool **500** causes the piston **530** to move axially upwardly from the position shown in FIG. **1**B to the position shown in FIG. **1**C. A small amount of flow can move through the piston chamber **535** and through nozzles **575** to the annulus **22** as the tool **500** starts to expand. As the piston **530** moves axially upwardly in pocket recesses **516**, the piston **530** engages the drive ring **570**, thereby causing the drive ring **570** to move axially upwardly against the moveable arms **520**. The arms **520** will move axially upwardly in pocket recesses **516** and also radially outwardly as the arms **520** travel in channels **518** disposed in the body **510**. In the expanded position, the flow continues along paths **605**, **610** and out into the annulus **22** through nozzles **575**. Because the nozzles **575** are part of the drive ring **570**, they move axially with the arms **520**. Accordingly, these nozzles **575** are optimally positioned to continuously provide cleaning and cooling to the cutting structures **700** disposed on surface **526** as fluid exits to the annulus **22** along flow path **620**.

The underreamer tool **500** may be designed to remain concentrically disposed within the borehole. In particular, the tool **500** in one embodiment preferably includes three extendable arms **520** spaced apart circumferentially at the same axial location on the tool **510**. In one embodiment, the circumferential spacing would be approximately 120 degrees apart. This three-arm design provides a full gauge underreaming tool **500** that remains centralized in the borehole. While a three-arm design is illustrated, those of ordinary skill in the art will appreciate that in other embodiments, tool **510** may include different configurations of circumferentially spaced arms, for example, less than three-arms, four-arms, five-arms, or more than five-arm designs. Thus, in specific embodiments, the circumferential spacing of the arms may vary from the 120-degree spacing illustrated herein. For example, in alternate embodiments, the circumferential spacing may be 90 degrees, 60 degrees, or be spaced in non-equal increments. Accordingly, the secondary cutting structure designs disclosed herein may be used with any secondary cutting structure tools known in the art.

Referring to FIG. **2**, a perspective view of a block according to embodiments of the present disclosure is shown. In this embodiment, a cutter block **200** is shown having two blades **220**A and **220**B, with a plurality of inserts **250** disposed on the blades **220**A and **220**B. As explained above, the block **200** having blades **220** carrying inserts **250** may be expanded when disposed in the wellbore, thereby allowing the inserts **250** to contact formation during, for example, reaming operations.

Referring to FIG. **3**, a perspective view of a reamer **300** according to embodiments of the present disclosure is shown. In this embodiment, reamer **300** includes a plurality of blocks **310**, with each block **310** having a plurality of blades **320**. As illustrated, block **310** includes a first blade **320**A and a second blade **320**B. Each blade **320** includes a plurality of cutting elements **325**. In this embodiment, first blade **320**A includes a first arrangement of cutting elements **330**A and a second arrangement of cutting elements **330**B. First blade **320**A includes a first stabilization section **335**A disposed proximate and axially above the first arrangement of cutting elements **330**A. First blade **320**A further includes a second stabilization section **335**B disposed proximate and axially above the second arrangement of cutting elements **330**B.

The second blade **320**B of block **310** also has a third arrangement of cutting elements **340**A and a fourth arrangement of cutting elements **340**B. Third arrangement of cutting elements **340**A are disposed at a axially distal location on blade **320**B and a third stabilization section **345**A is disposed proximate and axially above the third arrangement of cutting elements **340**A. Second blade **320**B further includes a fourth arrangement of cutting elements **340**B disposed above third stabilization section **345**A. Axially above the fourth arrangement of cutting elements **340**B, a fourth stabilization section **345**B is disposed.

Stabilization sections may be formed from various types of materials, such as tungsten carbide, diamond, and combinations thereof. In certain embodiments, stabilization sections may be formed from diamond impregnated materials. In still other embodiments, the stabilization sections may include a plurality of inserts, such as tungsten carbide inserts, diamond inserts, gauge inserts, wear compensation inserts, depth of cut limiters, and the like.

Referring to FIG. **4**, a perspective view of a reamer **400** according to embodiments of the present disclosure is shown. In this embodiment, reamer **400** includes a plurality of blocks **410**, with each block **410** having a plurality of blades **420**. As illustrated, block **410** includes a first blade **420**A and a second blade **420**B. Each blade **420** includes a plurality of cutting elements **425**. In this embodiment, first blade **420**A includes a first arrangement of cutting elements **430**A and a second arrangement of cutting elements **430**B. First blade **420**A includes a first stabilization section **435**A disposed proximate and axially above the second arrangement of cutting elements **430**B.

The second blade **420**B of block **410** also has a third arrangement of cutting elements **440**A and a fourth arrangement of cutting elements **440**B. Third arrangement of cutting elements **440**A is disposed at a axially distal location on blade **420**B. Fourth arrangement of cutting elements **440**B is disposed on second blade **420**B axially above the third arrangement of cutting elements **440**A. A second stabilization section **445**A is disposed proximate and axially above the fourth arrangement of cutting elements **440**B.

In this embodiment, block **410** further includes a third stabilization section **450** disposed axially above first arrangement of cutting elements **430**A and third arrangement of cutting elements **440**A and axially below second arrangement of cutting elements **430**B and fourth arrangement of cutting elements **440**B. Third stabilization section **450** may extend partially or completely between first and second blades **420**A and **420**B.

In still further embodiments, the layout of cutting element arrangements and stabilization sections may be adjusted to optimize drilling. For example, in certain embodiments, one or more additional stabilization sections may be disposed on first blade **420**A and/or second blade **420**B before the first and second arrangements of cutting elements **430**A and **440**B, or alternatively, a stabilization second may be disposed to extend partially or completely between first and second blades **420**A and **420**B, similar to the third stabilization section **450**, above. In still other embodiments, rather than have first and second stabilization sections **435**A and **445**A, reamer **400** may have a stabilization section, similar to third stabilization section **450** disposed above the second and fourth arrangement of cutting elements **430**B and **440**B, and extending partially or completely between first and second blades **420**A and **420**B.

Those of ordinary skill in the art will appreciate that by varying the relative location of cutting elements arrangements and stabilization sections, drilling dynamics may be optimized. According to the above described embodiments, the extra stabilization sections, compared to conventional reamers provide extra stabilization that may help to achieve better control of the reamer during drilling. The extra stabilization sections may further help recentralize the reamer/under-reamer with the pilot hole trajectory, thereby decreasing potentially damaging vibrations and improving drilling. Additionally, be dividing the cutting elements into additional cutting element arrangements and removing rock in stages, improved cleaning and cuttings removal may occur. Because the cleaning and cuttings removal is improved, the hydraulics around the cutting elements may be improved, thereby improving cutting element life and thus improving the efficiency of the reamer.

Referring to FIG. **5**, a side view of a block **1500** according to embodiments of the present disclosure is shown. In conventional expandable reamer design, a block consists of one or two blades. However, such symmetrical designs generate harmonics and increase vibrations that may damage the reamer or drilling tool assembly. Block **1500** illustrates an asymmetrical design, wherein block **1500** includes three blades **1505**A, **1505**B, and **1505**C. A plurality of cutting elements **1510** is disposed on each of blades **1505**A, **1505**B, and **1505**C. Flow channels **1515**A and **1515**B are formed between blades **1505**A, **1505**B, and **1505**C, thereby allowing fluids to flow through remove cuttings dislodged during reaming.

Referring to FIG. **6**, a side view of a block **1600** according to embodiments of the present disclosure is shown. Block **1600** illustrates an asymmetrical design, wherein block **1600** includes three blades **1605**A, **1605**B, and **1605**C. A plurality of cutting elements **1610** is disposed on each of blades **1605**A, **1605**B, and **1605**C. Flow channels **1615**A and **1615**B are formed between blades **1605**A, **1605**B, and **1605**C, thereby allowing fluids to flow through remove cuttings dislodged during reaming.

Referring to FIGS. **5** and **6** together, FIG. **5** specifically shows a block **1500** with a forward set asymmetrical blade configuration. In such a configuration, the leading blade **1505**A extends outwardly from the block **1500**. In another embodiment illustrated in FIG. **6**, block **1600** has a reverse set asymmetrical blade configuration, wherein the trailing blade **1605**C extends outwardly from the block **1600**. In both embodiments, the blades **1505** and **1605** are asymmetrical with respect to the block center, which breaks up harmonics and reduces reamer vibrations.

Those of ordinary skill in the art will appreciate that the amount the blades **1505** and **1605** are offset from the bit center will depend on the specific requirements of the reaming operation. Additionally, in certain embodiments, more than three blades **1505** and **1605** may be used, for example, in alternate embodiments, four, five, or more blades **1505** and **1605** may be used. Those of ordinary skill in the art will appreciate that the number of blades **1505** and **1605** per block **1500** and **1600** may vary depending on the diameter of the reamer on which the blocks are installed. Thus, smaller diameter reamers may have blocks **1500** and **1600** carrying less blades **1505** and **1605** than relatively larger diameter reamers.

Referring to FIG. **7**, a side view of a block **1700** in accordance with embodiments of the present disclosure is shown. In this embodiment, block **1700** illustrates a symmetrical blade configuration, wherein the block **1700** has four blades **1705**A-D. Flow channels **1715**A-**1715**C are formed between blades **1705**A-D, and a plurality of cutting elements is disposed on each of blades **1705**A-D. The symmetrical blade configuration of FIG. **7** illustrates an expanded cutting structure, as the cutting structure extends beyond an open slot in the reamer body. Expanded cutting structure increases the volume of diamond without compromising the cutting structure cleaning efficiency. Thus, a greater volume of diamond may allow for better rock removal, decreased cutter wear, and improved hydraulics.

Conventional expandable reamers included an open slot configured to receive the block when the reamer was in a compressed condition. During use, the block radially expands out of the slot into engagement with the formation, as described above. Embodiments of the present disclosure provide for a reamer having an open slot, such that in a compressed condition, the block is retracted into the open slot along with center blades **1705**B and **1705**C, while outer blades **1705**A and **1705**D are retracted into the body of the tubular, thereby allowing the reamer to be run into a wellbore. Upon actuation of the reamer, the block expands radially, thereby expanding all four blades **1705**A-D into contact with the formation. As explained above, the increased diamond volume may allow for more efficient removal of rock, while the increased number of channels **1715**A-C allows for efficient cleaning of the cutting structure. Those of ordinary skill in the art will appreciate that the size, i.e., length, of the expanded cutting structure may be optimized to have the most cutting elements, and thus diamond, possible while making the expanded cutting structure as short as possible, in order to provide for a more stable reamer.

Referring to FIG. **8**, a side view of a reamer according to embodiments of the present disclosure is shown. In this embodiment, a reamer **1800** having a blade **1805** is illustrated. Blade **1805** has a first arrangement of cutting elements **1810** and a second arrangement of cutting elements **1815**. Blade **1805** also has a stabilization section **1820**. Blade **1805** also has a second stabilization section **1825**, which is a pilot conditioning section. The second stabilization section **1825** provides a gage surface that offsets bending moments exerted by the reamer cutting structure during reaming. Additionally, second stabilization section **1825** helps to reduce excessive cutter loading and resultant vibrations that may damage the cutting structure or otherwise result in less efficient reaming.

Referring to FIG. **9**, a side view of a reamer according to embodiments of the present disclosure is shown. In this embodiment, a reamer **1900** having a blade **1905** is illustrated. Blade **1905** has a first arrangement of cutting elements **1910**, a second arrangement of cutting elements **1915** that extends radially further than the first arrangement of cutting elements **1910**, and a third arrangement of cutting elements **1920**. Each arrangement of cutting elements **1910**, **1915**, and **1920** have a plurality of cutting elements **1925** disposed thereon. Blade **1905** has a first stabilization section **1930** disposed below the third arrangement of cutting elements **1920** and above the second arrangement of cutting elements **1915**. Blade **1905** also has a second stabilization section **1935** disposed between the second cutting elements arrangement **1915** and the first cutting element arrangement **1910**, and a third stabilization section **1940** disposed below the first cutting elements arrangement **1910**.

Reamer **1900** illustrates a reamer having multiple stage reaming blades **1905**. Reamer **1900** includes three areas of stabilization, **1930**, **1935**, and **1940**. Thus, during drilling, third stabilization section **1940** contacts the wellbore wall as the first arrangement of cutting elements **1910** engages formation. As the diameter of the wellbore increases as a result of the first arrangement of cutting elements **1910** drilling the formation, second stabilization section **1935** contacts the enlarged portion of the wellbore, thereby stabilizing the reamer **1900**, such that when the second arrangement of cutting elements **1915** engages the formation, cutter loading and vibrations are reduced. The second arrangement of cutting elements **1915** may then drill the formation, expanding the wellbore to a final diameter. When the diameter of the wellbore is increased to a final diameter, the first stabilization section **1930** may contact the wall of the wellbore, thereby further stabilizing the reamer **1900**, further increasing the efficiency of the reaming operation.

Those of ordinary skill in the art will appreciate that in certain embodiments, reamer **1900** may have more than two stages. For example, reamer **1900** may have a third stage, wherein the third arrangement of cutting elements **1920** extends radially further than the second arrangement of cutting elements **1915**. Such an embodiment may allow the diameter of the wellbore to be increased to a larger diameter in three stages. Reaming in stages allows the reamer **1900** to be stabilized at the cutting structure level, thereby reducing the magnitude of imbalance forces, damaging vibrations, and excessive cutter loading.

Referring to FIGS. **10**A and **10**B, a top view and side view, respectively, of a reamer block according to embodiments of the present disclosure is shown. In this embodiment, a block **1000** is shown having two blades **1005**A and **1005**B. Each blade **1005**A and **1005**B has a plurality of cutting elements **1010** disposed thereon. Each blade **1005**A and **1005**B also has a plurality of depth of cut limiters **1015** disposed thereon. As illustrated, the depth of cut limiters **1015** are disposed behind the cutting elements **1010** on each blade **1005**A and **1005**B. While depth of cut limiters may engage the formation at some point during drilling, they do not actively cut the formation, rather, the depth of cut limiters may prevent damage to blades **1005** and or cutting elements **1010** from inadvertent blade **1005** to sidewall contact. The depth of cut limiters **1015** may be formed from various materials including, for example, tungsten carbide, diamond, and combinations thereof. Additionally, depth of cut limiters **1015** may include inserts with cutting capacity, such as back up cutters or diamond impregnated inserts with less exposure than primary cutting elements **1015**, or diamond enhanced inserts, tungsten carbide inserts, or other inserts that do not have a designated cutting capacity. While depth of cut limiters **1015** do not primarily engage formation during drilling, after wear of the cutting elements **1010**, depth of cut limiters **1015** may engage the formation to protect the cutting elements **1010** from increased loads as a result of worn cutting elements **1010**.

After depth of cut limiters **1015** engage formation, due to wear of the cutting elements **1010**, the load that would normally be placed upon the cutting elements **1010** is redistributed, and per cutter force may be reduced. Because the per cutter force may be reduced, cutting elements **1010** may resist premature fracturing, thereby increasing the life of the cutting elements **1010**. Additionally, redistributing cutter forces may balance the overall weight distribution on the cutting structure, thereby increasing the life of the tool. Furthermore, depth of cut limiters **1015** may provide dynamic support during wellbore enlargement, such that the per cutter load may be reduced during periods of high vibration, thereby protecting cutting elements **1010**. During periods of increased drill string bending and off-centering, depth of cut limiters **1015** may contact the wellbore, thereby decreasing lateral vibrations, reducing individual cutter force, and balancing torsional variation, so as to increase durability of the secondary cutting structure and/or individual cutting elements **1010**.

As shown specifically in FIG. **10**A, the depth of cut limiters **1015** are positioned between adjacent cutting elements. More specifically, the depth of cut limiter **1015**A is disposed between the apex of adjacent cutting elements **1010**A and **1010**B. Said another way, depth of cut limiter **1015**A is circumferentially offset from adjacent cutting elements **1010**A and **1010**B. By disposing the depth of cut limiter **1015**A between cutting elements **1010**A and **1010**B, the depth of cut limiters are configured to ride on a formation ridge generated between cutting elements **1010**A and **1010**B. Referring briefly to FIG. **10**C, a close-perspective representation of the reamer of FIGS. **10**A and **10**B, according to embodiments of the present disclosure is shown. FIG. **10**C illustrates cutting elements **1010**A, **1010**B, and depth of cut limiter **1015**A. As cutting elements **1010**A and **1010**B contact formation **1030**, an undrilled ridge **1035** forms therebetween. In the event of a sudden excessive weight-on-bit transfer to the reamer, depth of cut limiter **1015**A contacts the ridge **1035**, thereby reducing the magnitude of peak torque generated and limit damage to cutting elements **1010**A and **1010**B. Additionally, because depth of cut limiter ridge on ridge **1035**, excessive reamer vibration may be prevented, which may prevent damage to other components of the reamer.

Referring back to FIGS. **10**A and **10**B, in alternate embodiments a depth of cut limiter **1015** may be disposed on a blade in alignment with a cutting element of a different blade. For example, depth of cut limier **1015**B of blade **1005**A is aligned with cutting elements **1010**B of blade **1005**B. In another embodiment, depth of cut limiter **1015**A of second blade **1005**B may be aligned with cutting element **1010**C for first blade **1005**A.

In still other embodiments, at least one depth of cut limiter may be disposed so as to overlap with at least one cutting element. For example, depth of cut limiter **1015**A may be disposed to overlap with cutting element **1010**A and/or cutting elements **1010**C. In certain embodiments, the overlap may be limited to a certain diameter of the cutting element. For example, the overlap may be less than fifty percent of the diameter of at least one cutting elements. In other embodiments, the overlap may be forty percent, thirty percent, twenty-five percent, twenty percent, or less.

Advantageously, embodiments of the present disclosure may provide enhanced reamer block, blade, and cutting structure design to improve the operation of the reamer. Those of ordinary skill in the art will appreciate that the above identified methods for reducing vibrations, reducing magnitude of peak torque generated during excessive weight-on-bit transfer, offsetting bending moments, and reducing excessive cutter loading may be used alone or combined.

While the present disclosure has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the disclosure as described herein. Accordingly, the scope of the disclosure should be limited only by the attached claims.

What is claimed:

1. A secondary cutting structure for use in a drilling assembly, the secondary cutting structure comprising:
- a tubular body; and
- a block, extendable from the tubular body, the block comprising:
  - a first arrangement of cutting elements disposed on a first blade;
  - a first stabilization section disposed on the first blade and proximate the first arrangement of cutting elements;
  - a second arrangement of cutting elements disposed on the first blade; and
  - a second stabilization section disposed on the first blade and proximate the second arrangement of cutting elements.

2. The secondary cutting structure of claim **1**, wherein the block further comprises:

a third arrangement of cutting elements disposed on a second blade;

a third stabilization section disposed proximate the third arrangement of cutting elements;

a fourth arrangement of cutting elements disposed on the second blade; and

a fourth stabilization section disposed proximate the fourth arrangement of cutting elements.

3. The secondary cutting structure of claim **1**, wherein the block further comprises a second blade and wherein the first stabilization section extends between the first blade and the second blade.

4. The secondary cutting structure of claim **3**, wherein the second stabilization section extends between the first blade and the second blade.

5. The secondary cutting structure of claim **1** wherein the block further comprises:

an arrangement of cutting elements disposed on a second blade; and

a third arrangement of cutting elements disposed on a third blade.

6. The secondary cutting structure of claim **5**, wherein the third blade is asymmetrically offset with respect to a central axis of the block.

7. The secondary cutting structure of claim **6**, wherein the third blade is axially offset in a forward position.

8. The secondary cutting structure of claim **5**, wherein the third blade is axially offset in a reverse position.

9. The secondary cutting structure of claim **5**, wherein the block further comprises:

a fourth arrangement of cutting elements disposed on a fourth blade.

10. A secondary cutting structure for use in a drilling assembly, the secondary cutting structure comprising:

a tubular body; and

a block, extendable from the tubular body, the block comprising:

a first arrangement of cutting elements disposed on a first blade;

a first stabilization section disposed on the first blade and proximate the first arrangement of cutting elements;

a second arrangement of cutting elements disposed on the first blade; and

a second stabilization section disposed on the first blade and proximate the second arrangement of cutting elements; and

at least one depth of cut limiter disposed intermediate the apex of at least two adjacent cutting elements.

11. The secondary cutting structure of claim **10**, wherein the block further comprises:

a plurality of cutting elements disposed on a second blade; and

at least one depth of cut limiter disposed intermediate the apex of at least two adjacent cutting elements of the second plurality of cutting elements.

12. The secondary cutting structure of claim **11**, wherein the at least one depth of cut limiter of the first blade is in alignment with at least one cutting element of the second blade.

13. The secondary cutting structure of claim **10**, wherein the at least one depth of cut limiter overlaps with at least one cutting element.

14. The secondary cutting structure of claim **13**, wherein the overlap comprises less than 50 percent of the diameter of the at least one cutting element.

15. The secondary cutting structure of claim **10**, wherein the at least one depth of cut limiter is circumferentially offset from the two adjacent cutting elements.

* * * * *